Water is the Connection:
Managing Pesticide Risk for Salmon Recovery

A Guide for Willamette Valley Farmers

Northwest Center for Alternatives to Pesticides

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The Northwest Center for Alternatives to Pesticides works to protect community and environmental health and inspire the use of ecologically sound solutions to reduce the use of pesticides.

Water, Source of Life

Water – abundant, pure and cool – is of vital significance in western Oregon. A dense network of streams and rivers fed by snow and rainwater filtered through mountain forest soils (Figure 1) supply millions of Oregon residents with drinking water,[1] power an economically robust agricultural economy, and are home to the state's most iconic fish – salmon and steelhead.

Clean and cold water is increasingly scarce in the Willamette Basin. Nearly half of the Basin's stream and river miles are currently considered to be severely biologically impaired.[2]

Toxic contamination, along with warm temperatures, sedimentation and low, dissolved oxygen levels is a problem in the Willamette River and its tributaries. Pesticides – which include insecticides, herbicides, fungicides, soil fumigants, and repellents – are the most commonly detected chemicals in the Basin.[3] More than a dozen of those pesticides have been determined to jeopardize the continued existence of salmon and steelhead.

Minimizing the need for pesticides is important for growers, not just for salmon and steelhead. Routine use of pesticides can result in pest resistance. Pesticides are costly. And when pesticides wipe out beneficial organisms in addition to the target pest, secondary pest outbreaks may occur.

Alternative approaches to managing pests are available. In addition, simple actions – like planting trees on the perimeters of agricultural fields or learning to minimize drift – can have a powerful impact on water quality.

Figure 1. Major Rivers of the Willamette Basin

The Willamette River and its tributaries flowing from the Cascade and Coast Range comprise the drainage system of the Willamette Basin.

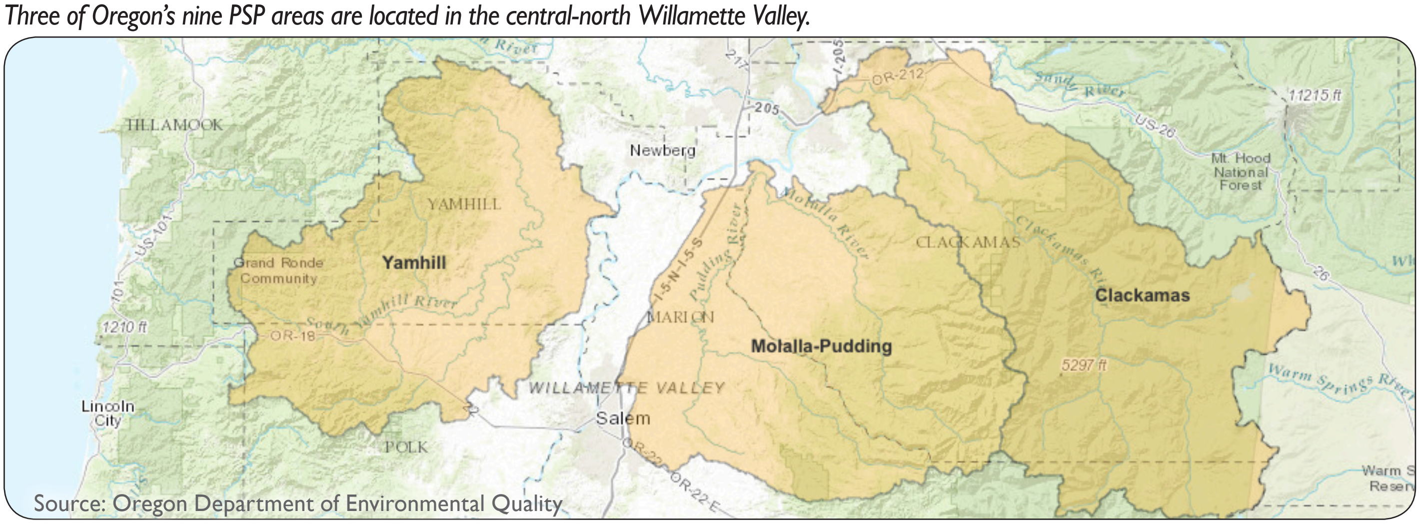
Source: Wikipedia https://commons.wikimedia.org/wiki/File:Willamette_river_map_new.png

This publication is designed to help pesticide applicators, especially in agriculture, learn about salmon in the Willamette Basin and the pesticides that are harmful to salmon or their food sources. Pesticide label language that indicates potential for aquatic contamination is explained. Voluntary Best Management Practices (BMPs) to minimize pesticide risk to aquatic habitats are included. Pesticide applicators can choose among these BMPs to reduce the risk of harming salmon.

Information is highlighted for the Clackamas, Molalla-Pudding and Yamhill subbasins (Figure 2), each part of the State of Oregon's Pesticide Stewardship Partnership (PSP) Program. Oregon's PSP works in selected Oregon watersheds, encouraging voluntary pesticide reduction with the goal of protecting water quality for aquatic life and human health.

Figure 2. Pesticide Stewardship Partnership Areas, Central-North Willamette Valley

Three of Oregon's nine PSP areas are located in the central-north Willamette Valley.



Source: Oregon Department of Environmental Quality

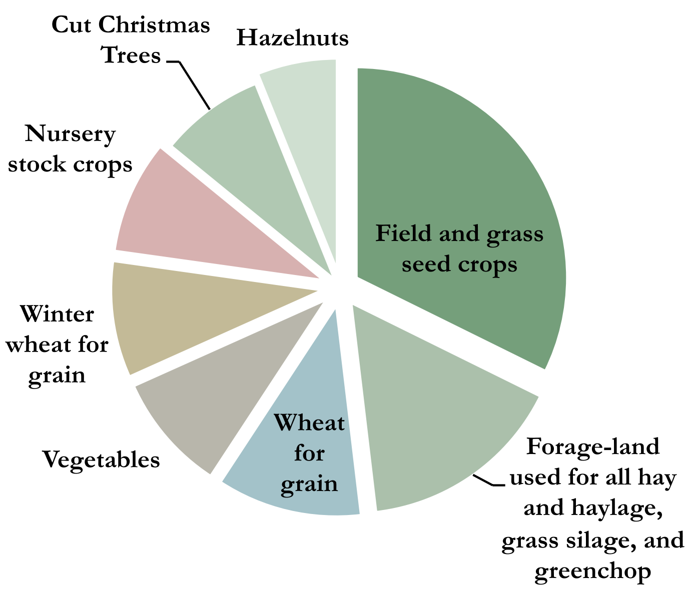
Agriculture in the Willamette Valley

The Willamette Valley contributes 40% of Oregon's total farm sales.[4] More than a million acres within the Willamette Basin are in agricultural use.[5] Winter precipitation drives the Valley's cropping pattern, resulting in an agricultural landscape dominated by grasses (including hay and pasture), perennial or tree crops that can be grown largely without irrigation and those annual crops that thrive in cool season temperatures or can be grown during a short summer. The Valley is known and loved for its berries, hazelnuts, wine grapes, nursery products, Christmas trees, and hops. In addition, Valley growers produce the lion's share of the nation's grass seed, grown for lawns and for forage on pasture across the country. Hay, wheat and vegetables are other significant crops commonly grown in the Valley.

In Clackamas, Marion and Yamhill Counties, approximately two-thirds of the agricultural lands are used to grow field and grass seed crops, forage (hay, silage, greenchop) and wheat (Figure 3). The remaining third produces vegetables, nursery stock crops, cut Christmas trees and hazelnuts.[6]

Some of the pesticides used in Valley agriculture and/or in urban areas have been detected in streams (Table 1).

Figure 3. Crops by Area
Clackamas, Marion and Yamhill Counties.
Grass seed, forage and wheat dominate agriculture in the three counties.



Source: USDA Census of Agriculture, 2012

Table 1. Selected Current-Use Pesticides Commonly Detected in Willamette Valley Streams

Active Ingredients	Common Trade Names
2,4-D*	2,4-D, Weed and Feed
Atrazine	Aatrex, Acuron, Anthem, Bicep
Bifenthrin*	Bifenture, Brigade, Bug B Gon
Carbaryl*	Sevin, Duocide, Liquid Fruit Tree Spray
Chlorothalonil*	Daconil, Echo, Equus,
Chlorpyrifos	Dursban, Lorsban, Nufos
DEET	DEET
Diazinon	Diazinon
Dichlobenil*	Casoron, RootX
Dichlorvos (DDVP)	Insect Shield, Nuvan Fog, Nuvan Prostrips
Dimethenamid	Frontier, Outlook
Dimethoate	Dimate
Diuron	Direx, Karmex
Ethoprop	Mocap
Glyphosate*	Accord, Aqua Star, Rodeo, Roundup, Touchdown
Imidacloprid*	Admire, Brigadier, Gaucho, Merit, Nuprid
Linuron	Linex
Methiocarb	Mesurol
Methomyl	Annihilate, Corrida, Lannate
Metolachlor	Bicep, Cinch, Dual, Lumax, Me-Too-Lachlor, Parallel
Metribuzin	Axiom, Sencor, Tricor
Metsulfuron Methyl	Escort, Oust, Patriot, Report
Norflurazon	Solicam
Oxyfluorfen	Cleantraxx, Galigan, Goal, Double O, Oxyflo
Pendimethalin*	Freehand, Pendulum, Prowl, Scotts Lawn Pro
Propiconazole	Quilt, Stratego, Propicon
Pyraclostrobin*	Bonide Fruit Tree and Plant Guard, Headline, Priaxor
Simazine	Princep, Sim-Trol
Sulfometuron-methyl	Landmark, Oust, SFM, Spyder

* Active ingredient also found in retail products for home/garden use.

Chinook salmon (juvenile) | Photo: Roger Tabor (USFWS)

Salmon And Steelhead in the Willamette Basin

The Willamette Basin has sustained salmon and steelhead (salmonids) for 15 million years. Despite their recognized economic, cultural and ecological significance, fish populations are in trouble. Hope for recovery rests on a concerted, broad-based effort to implement conservation actions in the recently developed recovery plans.[7]

More than a million salmon and steelhead once returned each year to the Basin. But today, the Chinook salmon, coho salmon and winter steelhead native to the Willamette Basin are all threatened by extinction.

Native salmon and steelhead are greatly diminished because of flood control and hydropower, the adverse impacts of land management, competition and predation by other species, overfishing, and hatchery impacts, according to the Upper Willamette Recovery Plan. Water quality is identified under the Plan as a significant threat to the Basin's native salmon runs. Water quality stresses are magnified because large portions of historical habitat are inaccessible due to dams and passage barriers. Thus, salmonids are forced to complete their life cycles in warmer, more polluted and degraded, low-lying portions of the Basin.

Salmon and Steelhead Use of Freshwater

Salmon and steelhead are cold-water fish that spend part of their lives in the ocean and part in freshwater. These fish use their sense of smell, which can detect chemical scents as low as a part per trillion, to migrate across thousands of miles.

Five native species and two non-native species of Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and coho salmon (*O. kisutch*) currently spawn in the Willamette Basin (Table 2).[8] Returning adult salmonids distribute in the Willamette River mainstem, its tributaries and upper headwaters, laying eggs in stream bottom gravels. Eggs develop over a period of several weeks. The young hatchlings (called "alevin" until they absorb their yolk sacs) emerge from the gravel as small fish known as fry. Juveniles rear in freshwater, with most Basin species rearing for one to two years – often in shallow, slower-moving, shoreline habitats or backwaters – before outmigrating to the ocean through the mainstem.

Freshwater habitats support salmonids in a range of life stages across the seasons. The life stages vary significantly in timing between species and can also vary between different populations or subbasins (generalized timing is displayed in Figure 4).

Salmon and steelhead are present in the Basin's freshwater, including many low-lying agricultural and urban reaches, each month of the year.

As they grow, juvenile fish must feed. Rearing areas must support prey in enough abundance and diversity to support the needs of growing salmon. Chinook salmon juveniles feed on larger aquatic insects such as caddisflies, mayflies, stoneflies, and other benthic (bottom-dwelling) organisms in faster-flowing riverine habitats. In slower waters with finer bottom substrates, terrestrial insects and midges are important foods. Copepods and daphnia make up a high proportion of the diet in reservoirs and in mainstems of large rivers. Juvenile steelhead prey also includes caddisflies, mayflies and stoneflies. Steelhead consume a wider variety of prey items than salmon.[9]

Figure 4. Freshwater Life History Stage Timing for Salmon and Steelhead in the Willamette Basin
The six species in the Basin exhibit different migration, spawning, and rearing timing. Generalized timing for each species is represented in the spirals, with each ring of the spiral representing one year in freshwater.

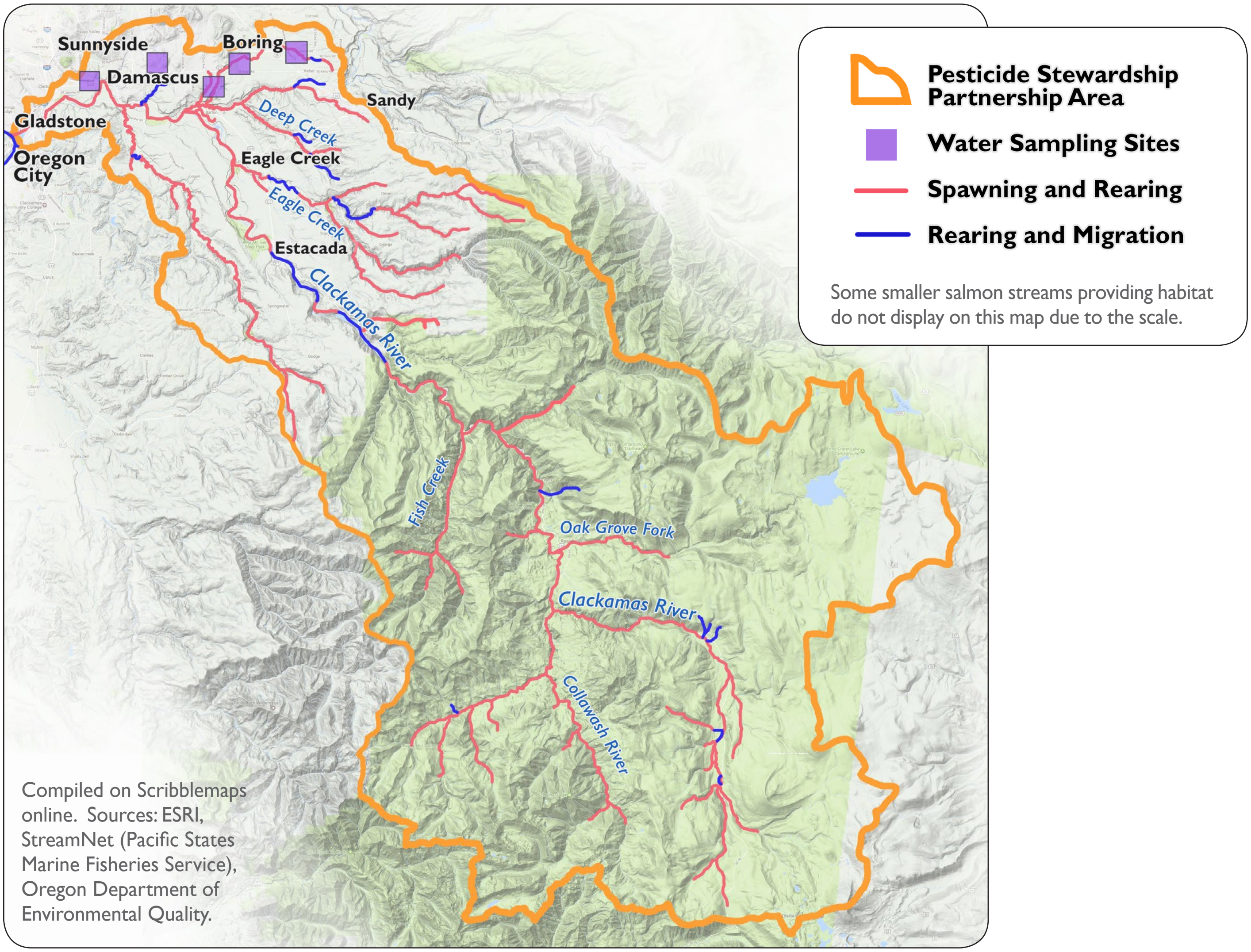
Table 2. Salmon and Steelhead of the Willamette Basin: Population and Distribution

Species common name	Evolutionarily Significant Unit* *(Endangered Species Act Status)*	Population Estimate		Historical Spawning Distribution	Current Spawning Locations	Rearing Locations and Habitats
		Historic	Current			
Spring Chinook salmon	Upper Willamette River Chinook *(Threatened)*	300,000	<10,000, adult returns are 80-90% hatchery-origins fish	Most tributaries draining the western Cascades. Satellite populations may have spawned in some western tributaries.	Core remaining populations in Clackamas, North Santiam, McKenzie, and Middle Fork Willamette	Subyearlings and yearlings rear in the mainstem Willamette River, tributary reservoirs, the Clackamas, McKenzie, and North and South Santiam.
Fall Chinook salmon	Lower Columbia River Chinook *(Threatened)*	Unknown	~9400, includes non-native populations	Originally restricted to sites downstream from Willamette Falls (primarily lower Clackamas).	Native population in Clackamas; introduced populations in N. Santiam, S. Santiam, McKenzie, Calapooia, and mainstem Willamette. Fall Chinook spawn in lower mainstem reaches compared to spring Chinook.	Mostly in the Columbia River estuary
Coho salmon (late run)	Lower Columbia River coho *(Threatened)*	Unknown	In Clackamas, average 3,375 (about 2/3 are natural origin spawners)	Clackamas River	Native run persists in Clackamas. Introduced stocks upstream of Willamette Falls, including Tualatin, Pudding, Yamhill, Molalla, mainstem and N. Fork Santiam Rivers	
Coho salmon (early run)	Not native	0	2000—3200	Not present	Introduced	Tributaries and mainstem of Clackamas
Winter steelhead	Upper Willamette River steelhead *(Threatened)* and Lower Columbia River steelhead *(Threatened).* This ESU includes the Clackamas population.	>200,000	Average 11,600 since 1950 (both early and late runs)	Primarily in Molalla, N. S. Santiam, Calapooia and Clackamas; limited spawning in west-side tributaries.	Core populations include the Clackamas, Molalla, N. Santiam, S. Santiam, Calapooia, and Clackamas. Small populations found in west-side tributaries.	Rear in spawning tributaries or reservoirs; rearing may also occur in lower reaches of the primary tributaries and in the main stem Willamette.
Summer steelhead	Not native	0	Average 14,300 (range up to 40,700) since 1970	Not present	Introduced. Primarily in Clackamas, Molalla, N. Santiam, S. Santiam, McKenzie, Middle Fork Willamette. Tend to occupy higher watershed areas than winter steelhead.	Shallow water along banks and stream margins. Some older juveniles move downstream to rear in larger tributaries and mainstem rivers.

*Evolutionarily Significant Units (ESUs - considered species under the Endangered Species Act) as designated at http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/salmon_and_steelhead_listings/salmon_and_steelhead_listings.html

Historic and current population estimates and distribution from various sources.[12]

Figure 5. The Clackamas Subbasin: Salmonid Habitat and Pesticide Monitoring Locations.
Spawning and rearing habitats are found from high elevations all the way to the Willamette River.



Distribution by Subbasin

Streams and rivers supporting salmon or steelhead in the Clackamas, Molalla-Pudding and Yamhill subbasins are displayed in Figures 5, 6 and 7, respectively. The figures also display sampling points where water is collected and analyzed for pesticide concentrations under the Oregon PSP program.

Clackamas

The Clackamas subbasin is very important to recovery, especially for spring Chinook salmon and coho salmon. It is one of the two (out of seven) Willamette subbasins supporting a significant, self-sustaining run of spring Chinook. The Clackamas also supports both an early and late run of coho salmon. The Clackamas population is important to recovery, as it is in better shape than most other Lower Columbia coho populations spawning in accessible Cascade-range streams.

The lower parts of the subbasin, below Estacada, also support fall Chinook with a population status considered very low. The Clackamas historically supported chum salmon, which some report as eradicated. The Recovery Plan lists its population status as very low.

Clackamas also supports a stable population of naturally-reproducing, winter-run steelhead, as well as a hatchery winter steelhead stock that is important below North Fork dam. Winter-run steelhead spawn and rear from the lowest part of the Clackamas mainstem through reaches extending into the high mountains. Introduced summer steelhead are also present in lower reaches of the subbasin.

Molalla-Pudding

This subbasin supports hatchery-origin spring Chinook, as the native wild run was extirpated in the 1960s. Poor habitat conditions exist within this subbasin.[10] Extinction risk for spring Chinook was rated very high within the Molalla-Pudding in the Recovery Plan. The subbasin also supports one of the four core sub-populations of winter-run steelhead upstream of Willamette Falls, with an extinction risk considered low. Summer steelhead are also found in the subbasin, the result of an ongoing hatchery release program.

Coho are also found within the subbasin (a legacy of past hatchery practices). According to recent surveys,[11] coho are currently the most numerous anadromous salmonids in the Pudding River Watershed, which occupies about half of the subbasin.

Yamhill

The Yamhill subbasin supports a small, winter-run steelhead population, though it is not known if the run derives from hatchery or native stock. Hatchery steelhead have established themselves in many tributaries draining the west side of the Willamette Valley. Although the subbasin does contain designated critical habitat for the winter steelhead, extinction risk for this subbasin was not addressed in the Recovery Plan, since the west-side tributaries were not considered to support independent salmon or steelhead populations prior to Euro-American settlement. However, juvenile Chinook and steelhead do rear in the Westside tributaries. Coho, derived from a discontinued hatchery program, are also self-sustaining in this basin.

Mainstem

All adult salmonids in this basin pass through the mainstem Columbia and lower Willamette Rivers as they migrate upriver. The Willamette River mainstem supports both winter steelhead and spring chinook at various life stages throughout the entire year. Spring chinook and summer steelhead often hold in the mainstem or in the lower reaches before heading to spawning sites. The Recovery Plan notes that 30-80% of adult spring Chinook that enter the Basin die – after entering freshwater but before spawning – for reasons not yet clearly understood.

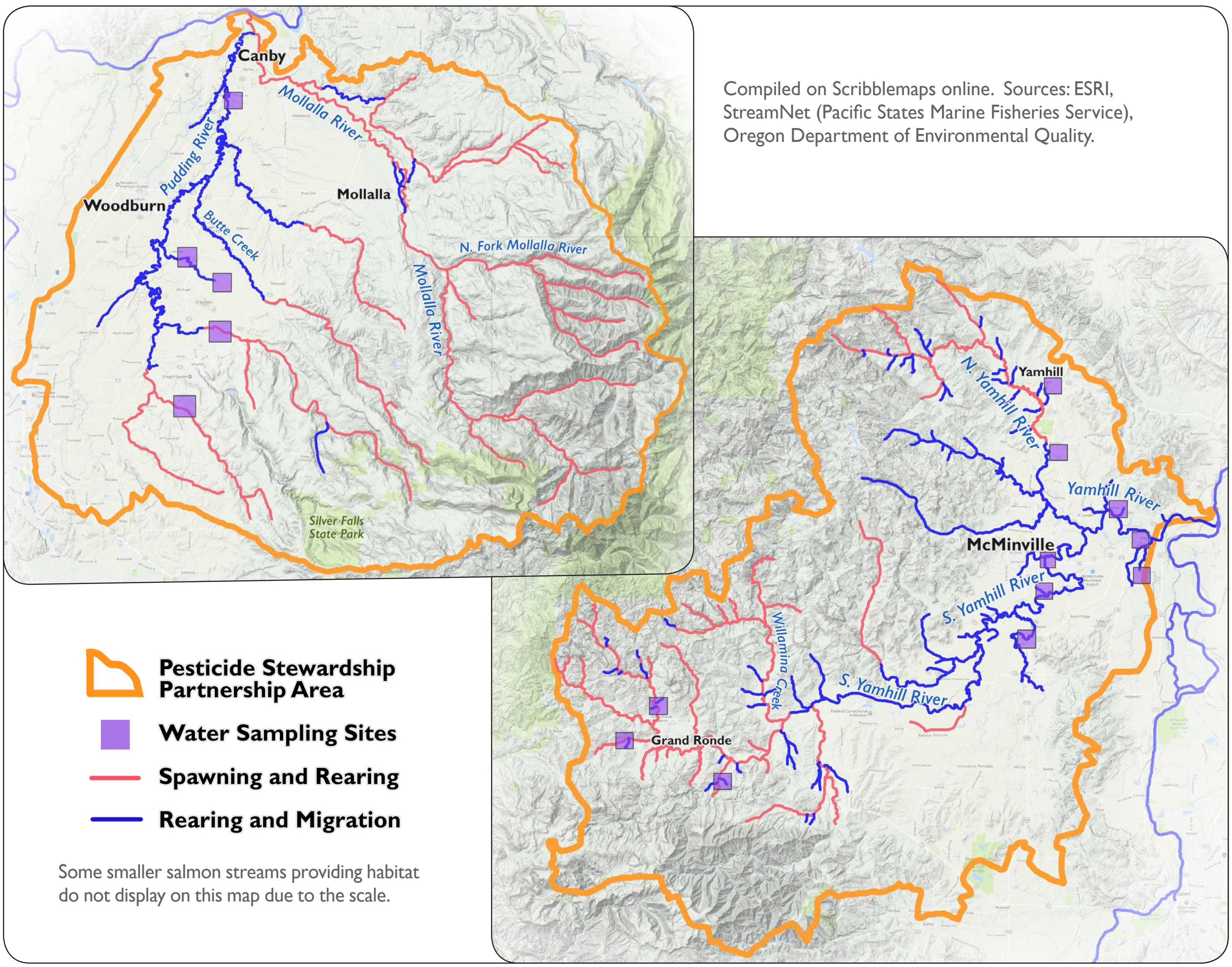


Figure 6. ***(left)*** **The Molalla-Pudding Subbasin: Salmonid Habitat and Pesticide Monitoring Locations.**
Figure 7. ***(right)*** **The Yamhill Subbasin: Salmonid Habitat and Pesticide Monitoring Locations.**
Spawning and rearing habitats are found from high elevations all the way to the Willamette River.

Recovering Endangered And Threatened Salmon & Steelhead

The Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead outlines the threats facing salmonids in the Willamette Basin. It also outlines goals, actions and priorities to bring the salmon and steelhead back to healthy population levels.[13] Finalized in 2011, the Recovery Plan emphasizes that recovery will depend not only on the protection of remaining high quality habitat but also the strategic improvement of degraded areas.

> **"We cannot achieve recovery of salmon and steelhead in the Upper Willamette while continuing the past and current practices that degrade salmon and steelhead habitat.**
>
> **Water quality necessary for recovery must be free from lethal levels of contamination… The combined effects of sublethal doses of pollutants are uncertain."**
>
> **– Recovery Plan**

Although many issues have caused the nearly 200-year record of decline that has resulted in the precariously low, current population numbers, the main problems that continue to impact salmon and steelhead within the geographic footprint of the Willamette Valley are degradation and loss of habitat due to land management and habitat blockage and impairment due to hydropower and flood control.

The Recovery Plan identifies several ways that land management impacts salmon habitat. One critical result is the degradation of water quality through toxins introduced from both agriculture and urban/industrial areas.

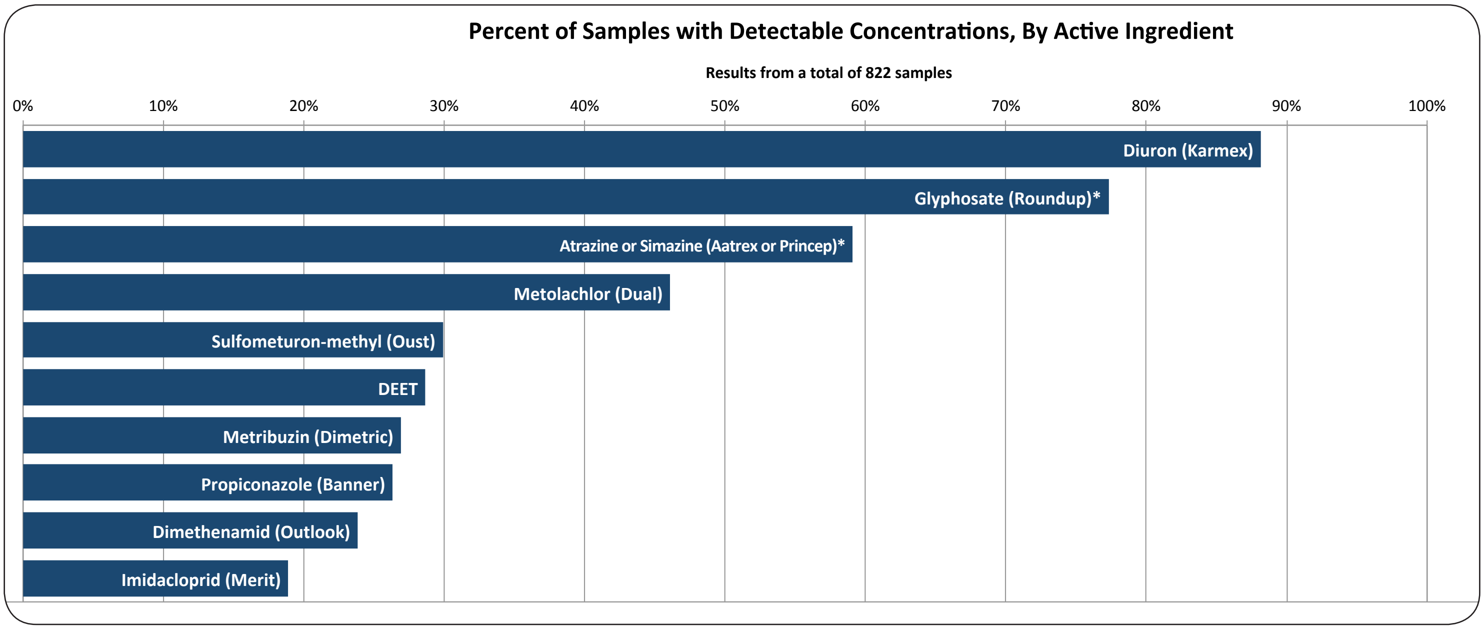
The Recovery Plan emphasizes the toxic impact of agricultural chemicals in all subbasins, especially to juvenile life stages. Adult fish were not identified as being at risk from toxins except in the mainstem Willamette where both agricultural and urban/industrial sources are identified as a concern. In general, the scale of the threat from toxins is considered more serious for Chinook.[14] Additionally, population reviews identified toxic contamination entering the migration corridor from multiple sources as a "growing concern."[15]

In line with the identification of toxins in water as a threat, the Recovery Plan includes, as one of the 14 overriding strategies: *"Restore degraded water quality and maintain unimpaired water quality."*

The Recovery Plan identifies, as a Priority 1 action, the reduction of *"non-point sourcing and loading of nutrients and pesticides from land use activities in subbasin streams [and] the Willamette River mainstem."*

Coho salmon | Photo: Bureau of Land Management

Figure 8. Ten Most Frequently Detected Pesticides in the Clackamas, Molalla-Pudding and Yamhill PSP Areas, 2010-2015.



Source: Oregon Department of Agriculture and Oregon Department of Environmental Quality, Pesticide Stewardship Program sampling data 2010-2015. Frequencies were calculated by aggregating data across all three subbasins.

* Atrazine and simazine are grouped since they are molecularly very similar. Frequencies for atrazine/simazine and glyphosate include both parent compound detections and their breakdown products (degradates).

Pesticide Problems for Fish

Certain pesticides are dangerous enough to cause fish kills. Other pesticides can kill or slow the growth of stream invertebrates (which salmonids rely upon for food) or stream algae (food for stream invertebrates). Still other pesticides disrupt the salmon sense of smell, interfere with brain chemicals or disrupt swimming behavior.[16]

Vulnerable Aquatic Habitats

Low flow, shallow habitats such as small streams, braided streams, backwaters, overflow (side) channels, and floodplains are used by rearing and migrating juvenile salmonids extensively.[17] Because they are protected from higher flows, they also provide less opportunity for dilution and dissipation of pesticide loads.

The Oregon PSP program tests aquatic pesticide concentrations at multiple locations within the Clackamas, Molalla-Pudding and Yamhill subbasins (Figures 5, 6 and 7). Sampling locations are located downstream of agricultural, urban, suburban, and forestry land uses. Some sampling points are located on smaller tributaries or creeks while others are on main rivers.

Samples are usually collected every two weeks, April through October. Water samples are "grabbed" from stream edges. This sampling technique collects dissolved pesticides and sediments suspended in the water column. Pesticides that tend to bind to soil (for example, bifenthrin strongly binds to soil) are not well sampled in this method.[20]

This section summarizes data collected April 2010 to October 2015, from all sample points included in the three subbasins for all dates sampled during the six-year period.

Frequently Detected Pesticides

Several broad-spectrum pesticides labeled for a wide variety of use sites are very frequently detected (Figure 8). The 10 most commonly detected pesticides in these PSPs, in order of frequency, are: diuron, glyphosate (or its degradate AMPA), atrazine or simazine or their degradates, metolachlor, sulfometuron-methyl, DEET, metribuzin, propiconazole, dimethanamid, and imidacloprid.[21]

All of these are herbicides except for propiconazole (a fungicide), DEET (mosquito repellent) and dimethanamid and imidacloprid (each insecticides). All are used in agriculture except DEET; half are also available for use in non-crop urban or residential settings.

Water Monitoring: A Tool for Measuring Pesticide Exposure

Testing water samples for pesticides is helpful for understanding the exposure of aquatic life, including salmon, to toxins. Five metrics are useful:

- ***Frequency (how often is a pesticide detected?)***
- ***Mean Concentration (how does the average concentration compare to toxicity thresholds?)***
- ***Maximal Concentration (how does the maximal concentration compare to toxicity thresholds?)***
- ***Mixtures (what mixtures are frequently seen and how does aquatic life respond to chemical mixtures?)***
- ***Trends (are concentrations of a pesticide generally increasing or decreasing over several years?)***

Frequencies and concentrations of pesticides vary widely by season, location and year. Maximal or peak concentrations in waterways are typically observed when rainfall or irrigation occurs soon after treatment. Mean concentrations are calculated by averaging all detected concentrations. Mean concentrations are not neccessarily "typical" since concentrations can vary widely in a body of water. Because data collection is not continuous and samples may miss actual high or low concentrations, actual peak concentrations can be higher than recorded, while actual mean concentrations may be higher or lower than the calculated value.

Toxicity measures the extent to which a pesticide is poisonous. Standardized toxicity tests expose a single species to a single pesticide in the lab. They are conducted by chemical manufacturers and summarized on Safety Data Sheets (SDS) for all registered pesticides.

Toxicity data is also available from lab tests conducted on species that are easily bred and maintained, such as rats, ducks and minnows. Such species are neither the most ecologically relevant or sensitive species affected in the real world. However, rainbow trout, a relative of steelhead and salmon, are often used as fish test subjects, and *Daphnia* (a common invertebrate test subject) are sometimes consumed by salmonids. Standard lab test results, sometimes supplemented by other studies examining other species or field studies, are used to interpret the toxicity of pesticides for people or other valued species such as salmon.

Standard toxicity tests measure the concentration of a single pesticide that causes death (or immobility) to the test subjects. Traditionally, the amount that kills 50% of the test population within a standardized time period (known as the lethal dose or LD_{50} or LC_{50}) is the value reported. Higher doses are more likely than low doses to result in death in short time frames.

Toxic effects can occur without the death of the test subject. These "sublethal" effects can be measured by observing test subjects for abnormalities, such as cancers, reproductive failure, growth inhibition, changes in enzyme activity, or other measurable problems. Investigations of sublethal effects are conducted with lower concentrations and reported as No Observable Effect Concentrations (NOECs).

Toxicity information is used to derive regulatory standards or non-regulatory benchmarks. Aquatic Life Benchmarks (ALBs or benchmarks)[18] are non-regulatory threshholds, based on the most sensitive, scientifically acceptable toxicity data available to the Environmental Protection Agency (EPA). ALBs are not yet designated for all pesticides and are unavailable for most pesticide breakdown products (degradates).

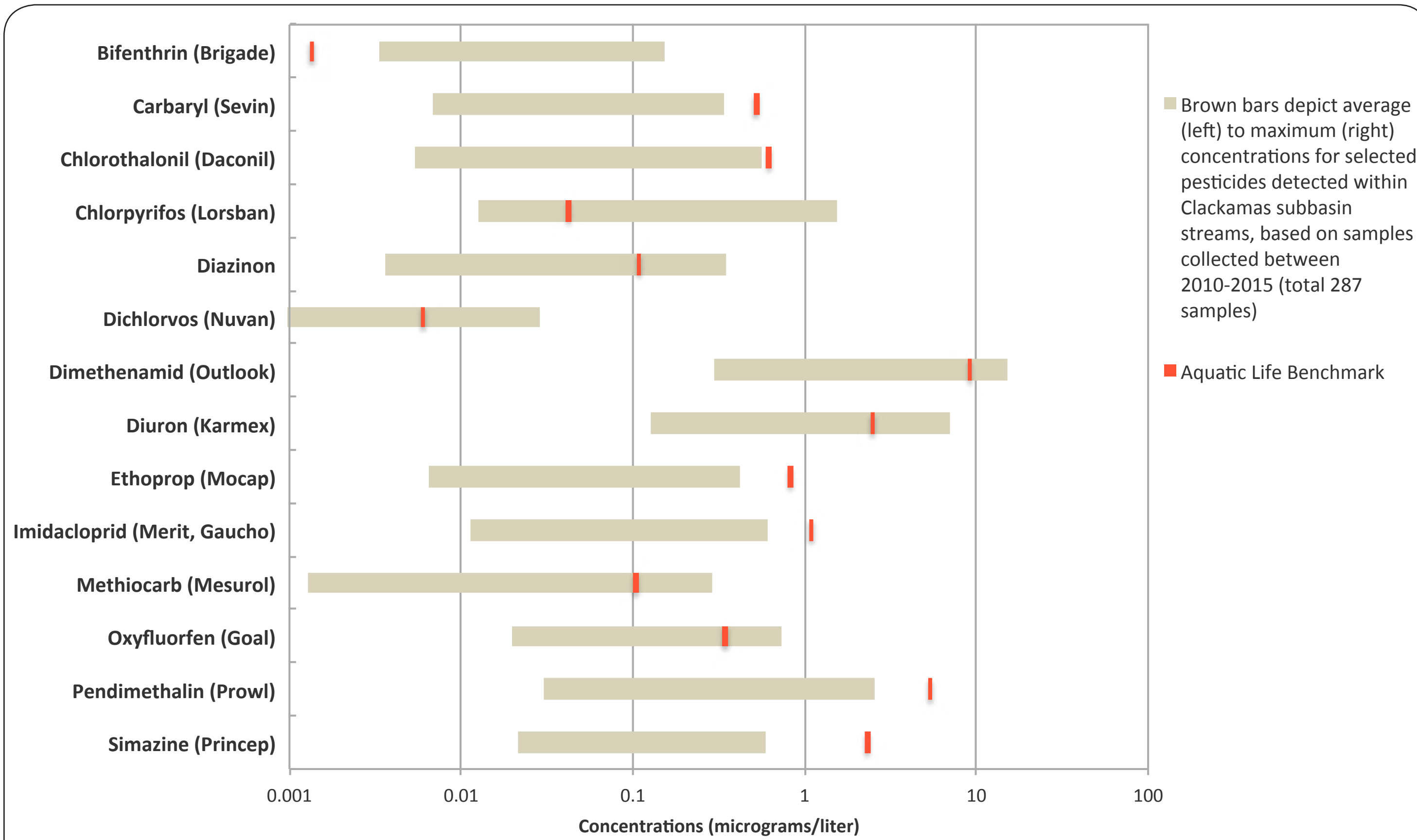
Concentration ranges can be compared to ALBs or regulatory standards to assess the hazard to aquatic life. A single exceedance may not be indicative of an ongoing problem or a significant threat to aquatic life; however, consistent or frequent exceedances may indicate a problem. Importantly, mixtures of multiple pesticides may result in toxicity at lower concentrations than predicted under benchmarks.

Benchmark exceedences and frequency of detection are both used by the State of Oregon in designating "pesticides of concern."

Because any monitoring program is limited,[19] toxicologists also use models to estimate pesticide exposures and durations.

Figure 9. Clackamas PSP:
Selected Current-Use Pesticide Concentrations Compared to Aquatic Life Benchmarks, 2010-2015

The farther to the left the benchmark (red) is compared to the range (tan), the greater the likelihood the pesticide is harming salmonid habitat in this subbasin.



The horizontal x-axis is displayed on a logarithmic scale. Each tick mark along the x-axis represents a multiple of 10.

Sources: -Oregon Department of Agriculture PSP Data, summarized across all sample points in the Clackamas PSP. Only pesticides with mean concentrations exceeding the benchmark, or maximal concentrations exceeding or approaching the benchmark, are displayed.
-Aquatic Life Benchmarks from the EPA. The most sensitive benchmark for each pesticide is displayed.

Problematic Pesticide Concentrations

Figures 9, 10 and 11 display the range of concentrations of selected pesticides in the three PSP subbasins from 2010-2015, with a focus on pesticides that exceeded or approached Aquatic Life Benchmarks (ALBs). The brown bars in the figures represent the range of concentrations between the mean and the maximum across all samples taken within the subbasin over the years 2010-2015. As apparent from the figures, differences of a hundred-fold between the mean concentrations[22] and maximal concentrations are common. The most sensitive EPA-designated ALB is represented in red. The further left the red benchmark is relative to the brown bar, the greater the concern.

Patterns of Concentration

- Atrazine and bifenthrin exhibited mean concentrations above their benchmarks.[23] This is a cause for concern as such a pattern indicates a consistent or ongoing problem. Atrazine mean concentration in all three subbasins exceeded the ALB, while bifenthrin mean concentration exceeded the ALB only in the Clackamas and Yamhill subbasins. Within the Molalla-Pudding subbasin, diuron concentrations are also a concern, with a mean concentration just slightly below the ALB.
- Many pesticides occasionally exceeded the ALB, but on average, were detected at concentrations below benchmarks. These pesticides also represent a cause for concern, though to a lesser degree, and include: 2,4-D, chlorpyrifos, diazinon, dichlorvos, dimethenamid, dimethoate, diuron, ethoprop, linuron, methiocarb, methomyl, metolachlor, oxyfluorfen, simazine, and sulfometuron-methyl.
- Several pesticides exhibited maximal concentrations that approached, but never exceeded the ALB (carbaryl, imidacloprid, chlorothalonil, ethoprop, metsulfuron methyl, oxyfluorfen and pendimethalin).

(Continued on p. 18)

Flameweeders, shown here managing weeds in a field, can also be used effectively for ditch management. | Photo: Holcomb Farm

"It Works Really Well" Ditch Management with Flameweeding

After high levels of the herbicide diuron (Karmex) were found in the Little Walla Walla River, Walla Walla Irrigation District Manager Teresa Kilmer began reconfiguring the district's approach to weed management. Vegetative biomass along the district's 29 miles of ditches had been managed with diuron for years, but diuron is very persistent and is harmful to salmon. Kilmer felt it was important to try a different approach.

To reduce weeds (reed canarygrass is typical) the district now relies heavily on "flameweeding" the ditches in fall, with a crew of three. A truck outfitted with a flamer and a 250-gallon propane tank flames the ditches while dry and a water tank follows behind to ensure that the fire remains contained. "It takes a couple of years of commitment, but it works really well for us," said Kilmer.

Weed-whacking to prevent seed set, occasional mechanical work with a backhoe and a limited amount of glyphosate are also used in place of diuron.

"We've had really good results with the burning," Kilmer reports. "We see a huge difference in spring if we've been able to knock the grass back through burning. The weeds don't come back nearly as thick in the spring."

And it's keeping the watershed cleaner. Diuron mean concentrations measured in the system have fallen 96% since 2009.

"You Have to have Passion"
Christmas Trees without Pesticides

"When we bought our property 34 years ago, we wanted sustainability," remembers Cathy Fantz, owner of Trillium Forest Farm in Eagle Creek, Oregon. Fantz uses no synthetic pesticides or herbicides on the property she manages with her husband Roger, which includes three acres of Christmas trees, timber, an orchard, berries, and a large vegetable garden.

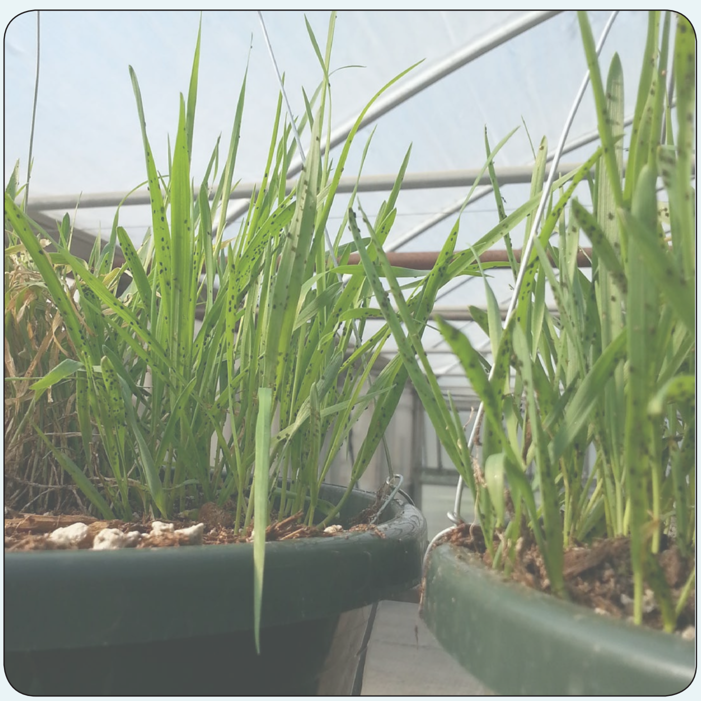
The Fantzes chose noble firs for the Christmas trees, because they are more disease-resistant than other local species. Site preparation was a matter of plowing and discing an area of native pasture on the property.

Christmas tree growers frequently use atrazine and other weed-killers and view grass as a stiff competitor. Fantz has learned to work with the weeds. She uses weedmat between trees in the row, prunes out the bottom whorl of fir branches and mows between rows two or three times a summer. "In some ways, the thick grass is helpful for keeping more problematic weeds down," reports Fantz. "However, many native plants also support beneficial insects, so we try to time mowing till after they flower."

Issues with aphids were occasionally a problem. "I would manually strip them from trunks and branches with my gloved hands. Then I noticed anthills near the affected trees, and realized the ants were cultivating the aphids. So we started knocking down the anthills and noticed an improvement."

"You have to have passion," Fantz remarks with a smile.

Cathy Fantz, owner of Trillium Forest Farm



Banker plants | Photo: Kelly Vance, Beneficial Insectary

"The Bios Work!"
Harnessing Nature in Nurseries

Beautiful flowers that brighten our foundation plantings can be subjected to high doses of insecticides at the nursery to keep the plants from looking chewed up before sale.

Industry pioneers have adopted biological controls to fight bugs instead of spraying them, reporting benefits in pest management, worker safety and the bottom line.

Kelly Vance, who worked as the Plant Health Manager at Fessler Nursery in Woodburn, Oregon before transitioning to a job with Beneficial Insectary, introduced "banker plants" to Fessler greenhouses. Banker plants, which Vance calls "miniature portable insectaries," use plant hosts to rear multiple generations of beneficial bugs that act as natural enemies to common greenhouse pests such as aphids, white flies, thrips, and spider mites. This economical system provides a constant source of natural enemies.

"We adopted the biological program originally because we were facing insecticide resistance," says Vance.

Predatory mites, applied in small sachets, fight thrips on ornamental starts.

Grassed ditch at Country Heritage Farms after planting
Photo: Sam Sweeny, Country Heritage Farms

Water samples show the difference a grassed ditch makes in filtering out sediment, compared to a bare ditch.
Photo: Sam Sweeney, Country Heritage Farms

"We were spraying the highest rates allowed on chemicals and we were noticing mounting pressure. The bugs were building a resistance. You can't build a resistance to getting eaten or having eggs laid in you by a parasite. The bios work!"

Bruce Colman, IPM Manager at Woodburn Nursery and Azalea in Woodburn, Oregon, spearheaded the nursery's effort to adopt the use of predatory mites – applied as small sachets – to fight thrips and mites.

"Nurseries don't want to waste chemicals because it's money down the drain," Colman explains. "Applying a broad-spectrum chemical, with the longest residual, targeting as large a group of pathogens as possible, is not IPM and it's not cost-effective. Reducing pesticides saves money. How do we do this? By scouting! Taking the time to scout opens up many possibilities for nurseries to control insects at reduced cost."

The commitment to use biocontrols allows Woodburn Nursery to generate sales based on a sustainably-grown stock.

"Keep the Soil in the Field" Cleaning Water Before It Runs Off

Sam Sweeney grows grass seed, hazelnuts, berries and vegetables at 1,600-acre Country Heritage Farms, a fixture in the Dayton area for generations. Decades ago, Sweeney noticed weeds invading his field edges, spreading from the state highway. Roadside weed spraying actually seemed to be making the problem worse. Sweeney decided to reshape the ditch, plant creeping red fescue and mow it two to four times a year. The results: no more crabgrass invading his fields, reduced and much cleaner runoff and less work for the state roads department. "It was an amazing difference!" Sweeney reports. "Roadside ditches are the plumbing system of a watershed. What is in these ditches is moved into the riparian systems and streams."

He didn't stop there. Field and tile runoff from his fields concentrates in a swale, then runs into a seasonal creek and ultimately feeds into the Yamhill River. With Natural Resources Conservation Service technical assistance and cost-share funds, Sweeney built a catchment basin at the tile outlet where the swale meets the creek. The catchment acts as a settling pond, allowing suspended soil particles to drop out before running into the creek. It also helps prevent gullying, which can occur during heavy storms. In addition to the catchment, Sweeney keeps a wide buffer of riparian trees and shrubs around the creek.

In field measures are important to Sweeney too. While he hasn't given up pesticides altogether, he has experimented with strip-till after cover crops in his vegetable fields, finding that – with the right equipment – it reduced the need for herbicides. And he is working with the Yamhill Soil and Water Conservation District to adapt a tunnel recycling sprayer for local growers, which will reduce drift when spraying berries and grapes.

Sweeney's pioneering work with conservation practices has resulted in several awards.

"Time the Flaming Perfectly" Innovative and Traditional Approaches Combine for Organic Success

Just outside of Gresham, Oregon, a 60-acre farm nestled near Johnson Creek produces oodles of vegetables. The Headwaters Farm Incubator Program, hosted by the East Multnomah Soil and Water Conservation District, has also set its sights on growing community connections and farmer education by offering five-year leases to new farmers.

Farmers tend individual plots with traditional, organic methods such as cover cropping to manage nutrients and weeds. Insect management techniques used at the farm include conservation biocontrol methods – including a beetle bank and pollinator hedge – and exclusion row covers to protect cole crops against flea beetles.

Rown Steele, the farm's manager, demonstrated a pre-emergent weed control method particularly promising for helping slower-germinating seed overcome early competition. Farmers place a four foot square plexiglass or glass plate over a small section of prepared and just-planted soil. Under the glass with its extra heat, the crop speeds toward germination. Seedlings springing up under the glass signal that crop seeds in the rest of the field are close behind – making it an ideal time to flame weed the first flush of weeds without harming the yet-emerged crop.

"Flame weeding is all about timing. Too soon, and the second flush of weeds will emerge at the same time as the crop germinates, defeating the point. Too late and you'll torch your emerging crop seedlings," explains Steele. "By covering the soil with glass or plastic, that super-micro climate provides enough extra warmth to offer a sneak-peek as to when the crop will be emerging. That way you can time the flaming perfectly."

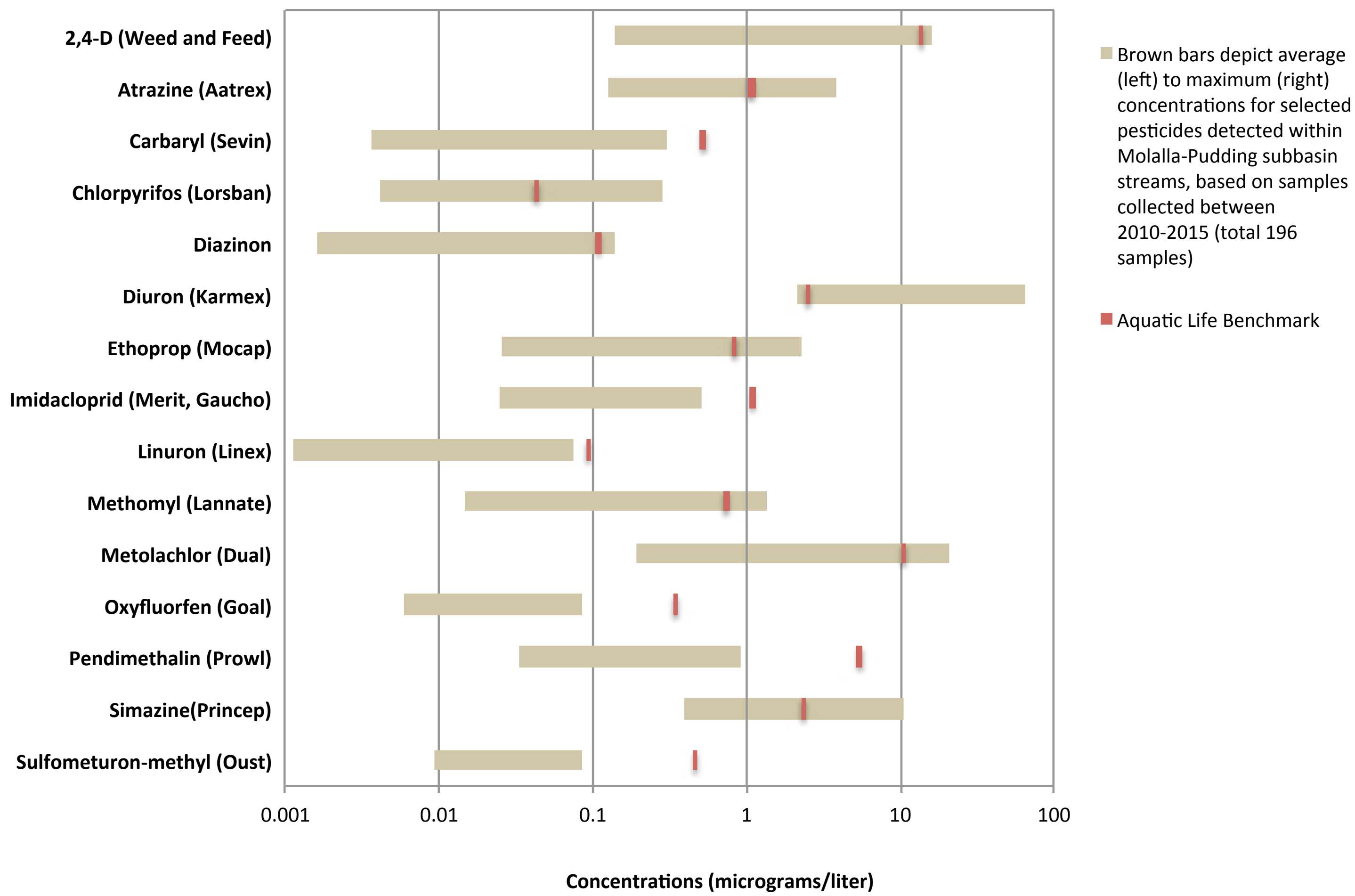
Heavy, UV-stabilized silage tarps offer weed seed bank reduction similar to solarization – without the long wait.

Several farmers also use 30-foot wide black "silage tarps" (made of heavy, UV-stabilized plastic) sourced inexpensively from a Canadian grain distributor. Functioning as a mulch, the tarps retain moisture and heat, allowing weed germination. But without light, weeds like thistle sprout and quickly die, reducing the seed bank. Steele reports that in the Northwest climate, such tarps are more effective than clear plastic solarization for battling perennial weeds, and the technique can be used for as little as three weeks in late spring to prepare a site for summer crops.

Twinberry, farewell-to-spring and pearly everlasting bloom over the season in the farm's pollinator hedge, which also supports nectar-seeking beneficial insects.

Figure 10. Molalla-Pudding PSP:
Selected Current-Use Pesticide Concentrations Compared to Aquatic Life Benchmarks, 2010-2015

The farther to the left the benchmark (red) is compared to the range (tan), the greater the likelihood the pesticide is harming salmonid habitat in this subbasin.



The horizontal x-axis is displayed on a logarithmic scale. Each tick mark along the x-axis represents a multiple of 10.

Sources:
-Oregon Department of Agriculture PSP Data, summarized across all sample points in the Clackamas PSP. Only pesticides with mean concentrations exceeding the benchmark, or maximal concentrations exceeding or approaching the benchmark, are displayed.
-Aquatic Life Benchmarks from the EPA. The most sensitive benchmark for each pesticide is displayed.

Trends and Mixtures

Trend analysis examines whether concentrations are generally increasing or decreasing over time. Trends can highlight shifting use patterns and are useful for designating priorities for action. Trends have not been systematically analyzed in the three PSP areas over the six-year period, but a cursory review determined that none of the pesticides highlighted in Figures 8, 9, 10, or 11 show consistent up or down trends across the three subbasins.

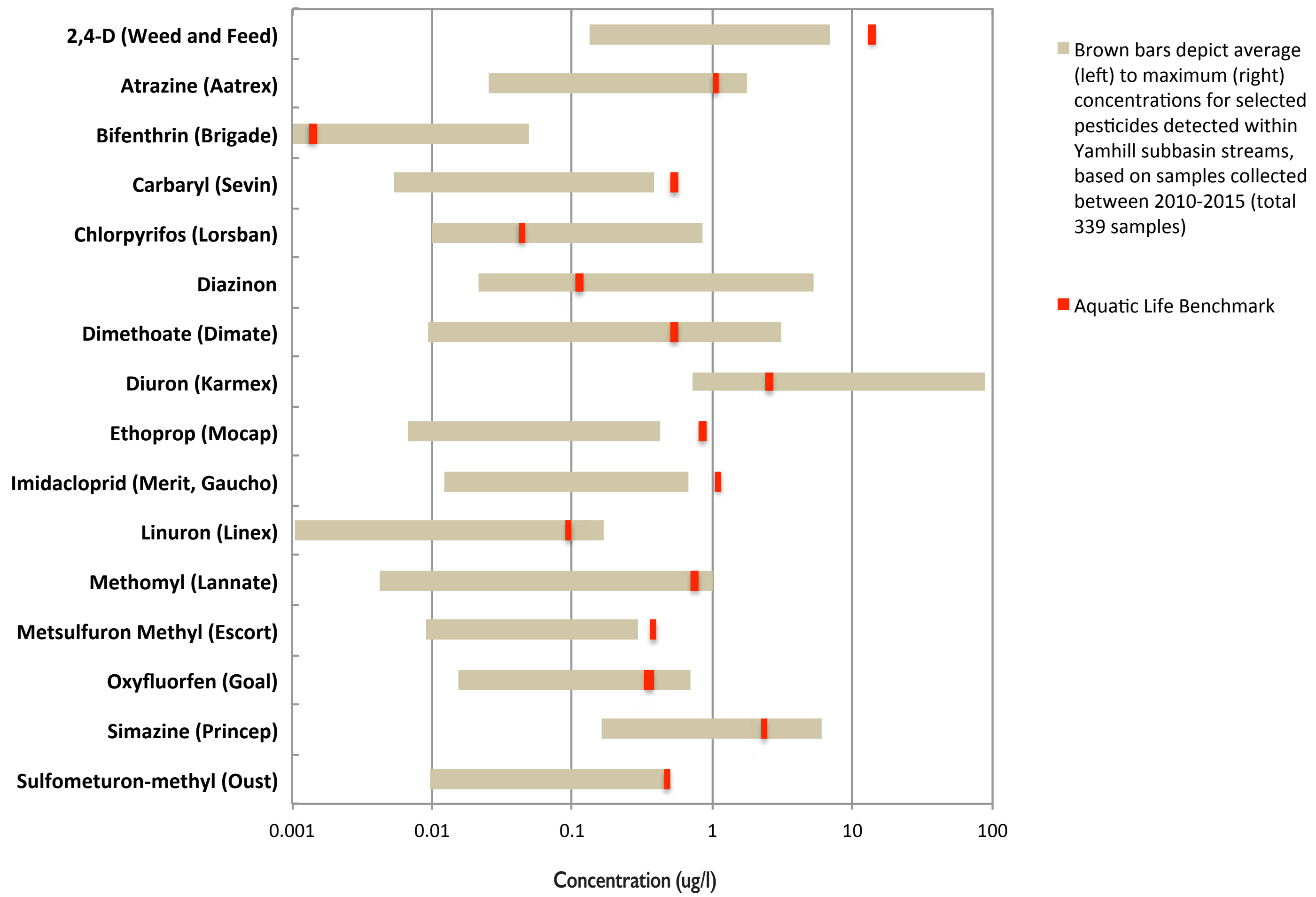
Mixtures are common, but analysis of recent data is incomplete. Previous studies in the Basin found that less than 4% of surface-water samples collected during 1994-2010 contained only a single detected chemical; mixtures of two to six pesticides each were found in the remaining samples.[24]

Synergistic (multiplicative) toxic effects are sometimes documented in studies of pesticide mixtures, especially mixtures containing organophosphate or carbamate insecticides or azole fungicides.

Understanding the combined toxic effect of multiple pesticides in streams (mixtures) is an evolving area of toxicology. Several reviews summarize test data showing that test subjects most often exhibit elevated effects from pesticide combinations; however the magnitude of these effects is usually predictable by summing the expected toxic effects of the individual pesticides in mixture ("concentration addition").[25]

Figure 11. Greater Yamhill PSP:
Selected Current-Use Pesticide Concentrations Compared to Aquatic Life Benchmarks, 2010-2015

The farther to the left the benchmark (red) is compared to the range (tan), the greater the likelihood the pesticide is harming salmonid habitat in this subbasin.



The horizontal x-axis is displayed on a logarithmic scale. Each tick mark along the x-axis represents a multiple of 10.

Sources:
-Oregon Department of Agriculture PSP Data, summarized across all sample points in the Clackamas PSP. Only pesticides with mean concentrations exceeding the benchmark, or maximal concentrations exceeding or approaching the benchmark, are displayed.
-Aquatic Life Benchmarks from the EPA. The most sensitive benchmark for each pesticide is displayed.

A review authored by Nina Cedergreen tested 136 pesticide binary mixtures (two pesticides combined) and reported that concentration addition explained toxic effects in the vast majority of combinations. Synergism (defined as a multiplicative, or enhanced, effect) explained toxic effects in 7% of combinations studied. Antagonistic effects were rare. Synergistic effects could reach 10 times the effect of additive effects; however Cedergreen pointed out that tests showing synergy were often conducted at concentrations higher than those typically found in monitoring efforts.[25]

Of the studies finding synergistic effects, nearly all involved organophosphate or carbamate insecticides, or azole fungicides. Pesticides in these groups regularly detected in surface water within the three PSP subbasins include chlorpyrifos, diazinon, carbaryl, methomyl, and propiconazole. Propiconazole is one of the top 10 most frequently detected pesticides detected, found in 26% of the samples collected from 2010-2015. Carbaryl was found in 11% of those samples.

Until this area of toxicology is better understood, waters with a history of samples showing residues of more than one pesticide, and especially waters containing organophosphate or azole fungicides in combination with other pesticides, should be viewed as potentially more toxic than predicted by adding the separate toxicities together.

Endangered Species Consultations:
Sixteen Pesticides Jeopardize Continued Existence of Salmon in the Valley

Congress passed the Endangered Species Act (ESA) in 1973 to protect animals and plants in danger of becoming extinct. The ESA requires that any Federal action, such as the registration of pesticides, does not harm species (or their habitat) "listed" under the ESA. If an action is so harmful that it is expected to threaten the continued survival of a listed, sea-going fish, the National Marine Fisheries Service (NMFS) issues a "jeopardy" determination in a Biological Opinion. Federal actions are also evaluated for their effects on habitat designated for endangered species (Critical Habitat). If the action is significantly harmful, NMFS issues an "Adverse Modification to Critical Habitat" determination within the Biological Opinion. Any Biological Opinion with a Jeopardy or Adverse Modification determination includes mitigations (called a "Reasonable and Prudent Alternative") in the Biological Opinion. The action agency (EPA) then is responsible for implementing the mitigations to ensure that the harm to listed species is minimal.

Since 2008, 54 pesticides have been considered for their effects on listed salmon and steelhead. Of these, 16 have been determined to jeopardize the continued existence of one or more salmonid species present within the Willamette Basin and/or cause adverse modification to the designated Critical Habitat (Table 3). The ball is in EPA's court to implement mitigations for these pesticides. Until that time, avoiding harm to salmon from these pesticides will depend on people choosing alternatives and implementing Best Management Practices (BMPs).

Nine additional pesticides are awaiting completion of Biological Opinions. Until complete, applicators must observe no-spray buffers (setbacks) when applying these chemicals (Table 4) adjacent to salmon-bearing streams. Required buffers are 60 feet for ground applications and 300 feet for aerial applications, until further notice. Limited exceptions exist.

Table 3. Pesticides Determined Harmful to Salmon Species or Individuals under Consultations

Pesticides determined to jeopardize the continued survival of one or more listed salmon species in the Willamette Basin (and/or cause adverse modification to Critical Habitat)

Active Ingredient	Trade Name
2,4-D	2,4-D, Weed and Feed
Carbaryl	Sevin,Duocide, Liquid Fruit Tree Spray
Carbofuran	(Cancelled)
Chlorothalonil	Daconil, Echo, Equus
Diflubenzuron	Dimilin, Clarifly, Truth
Dimethoate	Dimate
Diuron	Direx, Karmex
Fenbutatin oxide	Meraz, Vendex
Methomyl	Annihilate, Corrida, Lannate
Naled	Dibrom, Trumpet
Oryzalin	Amaze, Double O, Surflan, Weed Impede
Pendimethalin	Freehand, Pendulum, Prowl, Scotts Lawn Pro
Phorate	Thi-met
Phosmet	Imidan, Prolate
Propargite	Comite, Omite
Trifluralin	Buckle, Treflan, Trust

Source: NOAA Fisheries. Pesticide Consultations with EPA. http://www.nmfs.noaa.gov/pr/consultation/pesticides.htm

Table 4. Pesticides with Required Application Buffers for Listed Salmonids

No-spray buffers (setbacks) are required for applications adjacent to salmon-bearing waterways (60 feet for ground applications and 300 feet for aerial applications).

Active Ingredient	Trade Name
1,3- dichloropropene (1,3-D)	Telone, 1,3-D
Bromoxynil	Buctril, Maestro, Moxy
Carbaryl	Sevin,Duocide, Liquid Fruit Tree Spray
Chlorpyrifos	Durban, Lorsban, Nufos
Diazinon	Diazinon
Malathion	Fyfanon, Malathion
Methomyl	Annihilate, Corrida, Lannate
Metolachlor	Bicep, Cinch, Dual, Me-Too-Lachlor, Parallel
Prometryn	Caperol, Vegetable Pro

See maps and information online at Salmon Mapper: http://www.epa.gov/endangered-species/salmon-mapper

How Pesticides Get Into Water

Pesticides can unintentionally enter waterways through many routes (Figure 12), including:

- Drift (airborne transport of spray droplets by wind, warm air or inversions)
- Volatilization (evaporation of pesticides after application). Pesticide vapors transported in the air in a gaseous form can travel great distances and be subsequently deposited in water bodies through precipitation.
- Runoff (surface water transport of dissolved pesticides)
- Erosion (transport of pesticides bound to soils, often occurs in combination with heavy rainfall)
- Leaching (percolation of pesticides through the soil into groundwater). Groundwater connects with surface water, so pesticides in groundwater can create concerns for aquatic communities and for drinking water and irrigation use.

A pesticide is more likely to be a problem for salmonids when the pesticide is allowed to enter streams, is toxic at low concentrations to fish or their prey and is in widespread use.

Pesticides that are highly water soluble, not readily bound to soil and persistent can run off into streams or leach into groundwater. Table 5 describes how to interpret these characteristics and the property of vapor pressure, which indicates a pesticide's potential to evaporate shortly after application.

For reference, Table 6 displays chemical properties important in predicting runoff and leaching for selected pesticides detected in Willamette Valley streams.

Figure 12. Pesticide Movement in the Environment

Pesticides enter water via multiple routes.

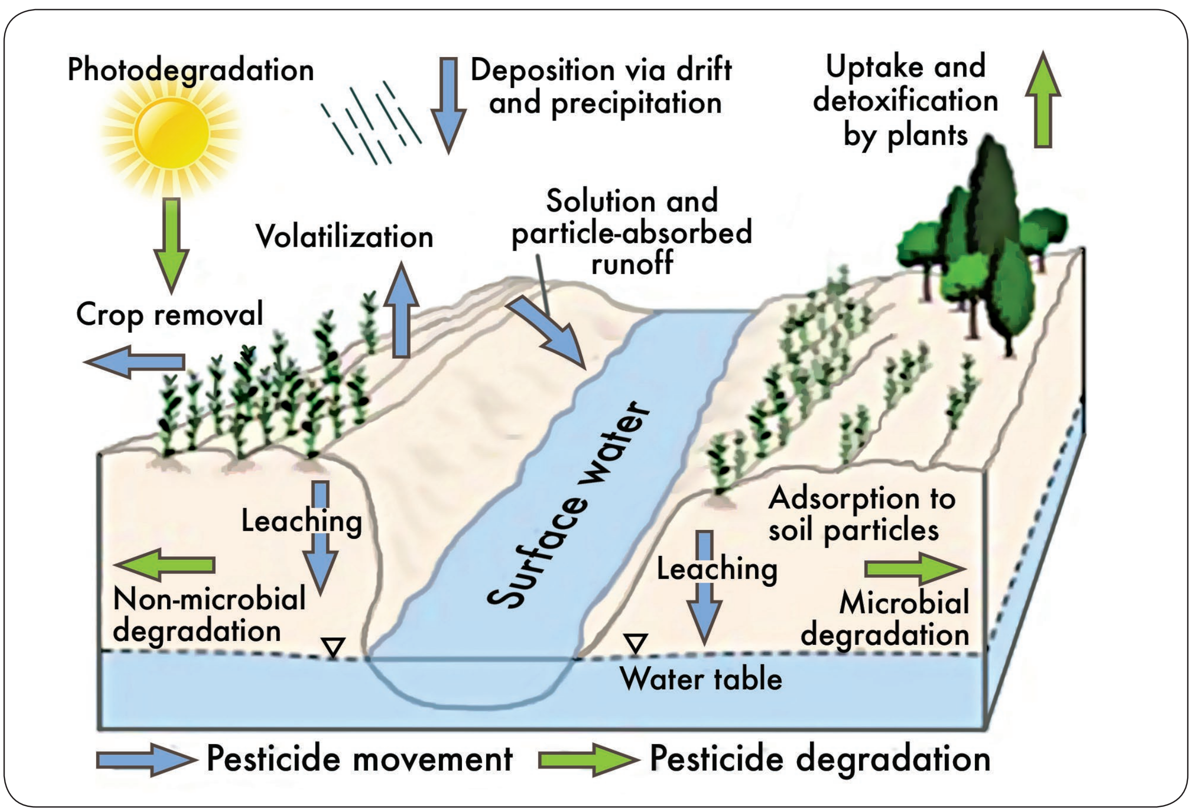


Table 5. Pesticide Properties Indicating Potential for Aquatic Contamination After Application

Property	Meaning	Why it Matters	Interpreting Values*	Examples
Water Solubility	Tendency to dissolve in water	More soluble pesticides dissolve easily, moving with rainfall or soil water into streams or groundwater.	The higher the value, the more soluble. Low: <10 ppm Moderate: 10-1000 ppm High: >1000 ppm	Glyphosate (Roundup): Highly soluble (Sol=12,000 ppm)
Sorption Coefficient (Koc)	Tendency to sorb (bind) to soil particles	Pesticides weakly attached to soil are easily moved by leaching or runoff, a phenomenon known as mobility. Sorption varies with soil texture, organic matter and moisture. For example, pesticides sorb less to sandier and wetter soils.	Koc values are normalized by the amount of organic material present in the sample. Lower sorption (Koc) values indicate greater mobility. Mobile: $\leq$ 100 Moderately Mobile: 100-10,000 Immobile: >10,000	Atrazine (Aatrex): Mobile (Koc=75)
Soil Persistence (Half-life)	Time for pesticide to break down to half of its previous concentration[26]	More persistent pesticides stick around, with increased opportunities to get carried to streams.	The higher the value, the more persistent. Non-persistent: <16 days Moderately persistent: 16-59 days Persistent : $\geq$60 days	Diuron (Karmex): Persistent (soil half-life =90 days)
Vapor Pressure	Tendency to evaporate after application	Pesticides that evaporate easily can move quickly off-site through the air, a phenomenon known as volatilization or vapor drift. Higher temperatures increase volatilization.	The higher the value, the greater tendency to volatilize. Low: < $1x10^{-6}$ mm Hg Moderate: $1x10^{-6}$—$1x10^{-2}$ mm Hg High: >$1x10^{-2}$ mm Hg	1,3-dichloropropene (Telone): (Vapor Pressure=23 mm Hg)

*Classification follows categories used by the National Pesticide Information Center (NPIC) at http://npic.orst.edu for solubility, soil persistence and vapor pressure. Classification of sorption follows EPA guidance and classification: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-reporting-environmental-fate-and-transport - II_C.[27]

Applicators should also be aware of site characteristics and pesticide application scenarios that are more likely to result in aquatic contamination.

Site Characteristics More Likely to Result in Aquatic Contamination:

- Proximity to water
- Sloped sites
- High water table
- Lack of vegetative, no-spray buffer along waterway
- Channeled runoff leaving field
- Fine particle (clay) or compacted soils
- Soils very dry or soils saturated
- Bare, compacted or highly permeable soils

Pesticide Application Scenarios More Likely to Result in Aquatic Contamination:

- Weather conditions that favor drift or volatilization (inversion conditions, temperatures above 70°F and relative humidity below 40%, or winds above 8 miles per hour)
- Heavy rainfall shortly after application
- Aerial spray or other application methods likely to result in drift
- High boom position
- Small droplet size (very fine and fine)

Soil erosion
Photo: East Multnomah Soil and Water Conservation District

Table 6. Chemical Properties for Selected Pesticides Observed in PSP Samples

Chemicals are ranked by water solubility. Highly soluble pesticides are more likely to be removed from the soil by runoff or by moving below the root zone with excess water.

Active Ingredient	Water Solubility (ppm)	Persistence: Soil Half-life (days)	Soil Binding (sorption)	Potential to Leach to Groundwater
Glyphosate isopropylamine salt (4)	900000	47	24000	Extremely Low
2,4-D dimethylamine salt (4)	796000	10	20	Moderate
Methomyl	58000	30	72	High
Dimethoate	39800	7	20	Moderate
Dichlorvos	10000	0.5	30	Extremely Low
Metsulfuron-methyl	9500	30	35	High
Metribuzin	1220	40	60	High
2,4-D acid (4)	890	10	20	Moderate
Ethoprop	750	25	70	High
Metolachlor	530	90	200	High
Carbofuran	351	50	22	Very High
Carbaryl	120	10	300	Low
Propiconazole	110	110	650	Moderate
Linuron	75	60	400	Moderate
Sulfometuron-methyl	70	20	78	Moderate
Diazinon	60	40	1000	Low
2,4-DB acid (2,4)	46	5	440	Very Low
Diuron	42	90	480	Moderate
Atrazine	33	60	100	High
Norflurazon	28	30	700	Low
Methiocarb	24	30	3000	Very Low
2,4-DB butoxyethyl ester	8	7	500	Low
Simazine	6.2	60	130	High
Chlorothalonil	0.6	30	1380	Low
Chlorpyrifos	0.4	30	6070	Very Low
Endosulfan	0.32	50	12400	Extremely Low
Pendimethalin	0.275	90	5000	Very Low
Oxyfluorfen	0.1	35	100000	Extremely Low
Bifenthrin	0.1	26	240000	Extremely Low

Source: OSU Pesticide Properties Database (http://npic.orst.edu/ingred/ppdmove.htm)

Alternative Strategies for Pest Management

Reducing Pest Pressure - Prevention

As Benjamin Franlin said, "an ounce of prevention is worth a pound of cure." Prevention is the best defense, is cost-effective and can be used at crop establishment and during crop maintenance.[28]

Crop Establishment

- Choose varieties resistant to disease and insects. Use certified, clean planting stock or high-quality seed certified to have low weed content (<0.25%).
- Promote crop vigor by maintaining healthy soil. Weeds often tell a story about the site's pH, drainage, fertility and compaction. Correct any known problems prior to planting.
- Rotate crops to interrupt weed, insect, and pathogen cycles. Good rotation strategies vary factors like root depth and biomass, nitrogen-fixing capacity, leaf density, alternate hosts, and time of sowing. Slow-developing crops are susceptible to weeds and should follow weed-suppressing crops. Rotation examples include: winter grass seed or cereals rotated with pulses or oilseeds; summer vegetables or row crops with winter cereals or legumes.
- Plant fast-growing, densely planted cover crops between annual cash crops to prevent weed establishment.
- Try companion crops to occupy space during the time it takes to establish slower growing crops.
- Use a "stale seedbed" technique when planting annual crops; prepare beds, encouraging a flush of weed germination – then destroy weeds before they have an opportunity to compete with the young crop.
- Soil solarization (heating soil to high temperatures during summer under thick UV-stabilized horticultural plastic) destroys many weeds and pathogens with effects lasting for months or longer. This method is a good alternative to the practice of fumigation.[29]
- Allocate a portion of the farm for native habitat and/or habitat attractive to native beneficial insects and pollinators, to promote natural biocontrol by beneficial insects.

Maintenance

- Avoid introduction of weed seeds and pathogens. Clean equipment between each field. Practice sanitation regularly.
- Maintain adequate organic material and soil nutrients. Prevent soil erosion and compaction.

Using Alternatives Benefits Growers

Benefits from using alternate strategies include:

- Slows development of pesticide resistance
- May lower production costs
- May reduce production interruptions otherwise necessary to observe restricted entry intervals after pesticide applications
- Helps maintain beneficial organisms (natural enemies)
- Reduces chances of secondary pest outbreaks
- May reduce chances of negative effects to the next crop cycle
- Delays burdensome regulation or loss of pesticide as a tool
- Creates opportunities for broader marketing and consumer acceptance
- Safer for people and pets, not just wildlife

Integrated Pest Management (IPM) Principles

- Work to understand the pest life cycle. Learn how and when to monitor. Scout early and often for pest presence.
- Use prevention methods as the first line of defense.
- Identify economic thresholds required for active pest suppression.
- Prioritize cultural, mechanical or biological suppression methods.
- Use pesticides only when justified by monitoring and after effective alternatives have been exhausted.

Sources for Information on Alternative Practices

- Oregon State University Extension (extension.oregonstate.edu)
- ATTRA Sustainable Agriculture (attra.ncat.org)
- eOrganic (eorganic.info)
- University of California Statewide Integrated Pest Management Program (ipm.ucanr.edu)
- Western SARE Learning Center (westernsare.org/Learning-Center)
- Northwest Center for Alternatives to Pesticides (pesticide.org)
- eXtension (eXtension.org)

- Plant grass, cover crops attractive to beneficial insects or use mulches between vineyard or berry rows or in orchard aisles.
- Where applicable, prune or otherwise increase light and airflow to reduce incidence of fungal or viral diseases benefitting from high humidity conditions.
- Combine cultural strategies to make the area less hospitable to pests. For example, trials combining narrower row spacing with higher seeding rates and banded fertilizer resulted in weed suppression in corn six times higher than in trials using only one of these strategies.[30]

Reducing Pest Pressure – Suppression

Some pest pressure is usually inevitable. When pests are present, alternative suppression techniques can frequently alleviate pest pressure[31] and minimize or eliminate the need for pesticides.

Weeds

- Mow or cultivate weeds prior to seed set.
- Shallow cultivation, cover crop roller-crimpers, flame weeders, infrared heaters or steam weeders can be used as alternatives to herbicides.

Insects

- Include management strategies for insects at various life stages. Often it is easier and more effective to attack larvae than to attack adults.
- Use exclusion or barrier techniques where feasible.
- Mass-trap pests using trap crops, baits or pheromone technology (chemicals produced by insects to communicate).
- Pheremones are also currently employed in mating disruption, effectively suppressing populations for approximately 20 species. EPA has registered >120 disruption products.
- Supplemental biological controls, botanical extracts and microbials are effective and widely available for managing many insect pests.
- Systems such as "banker plants" in greenhouses allow ongoing supplemental rearing of natural enemies (predators or parasites on the pest insect).
- Conserving or creating on-farm habitat such as beetle banks, cover crops, alley cover crops, or hedgerows supports native natural enemies (conservation biocontrol) and provides habitat for pollinators.
- Remove alternate hosts where feasible.

Diseases

- Certain cover crops (e.g. mustard) can substitute for soil fumigants.
- Manage humidity through irrigation techniques and pruning.
- Interrupt fungal life cycles using mulching, raking and flail mowing of prunings.

Pollinator and beneficial insect hedge row

Roller crimper – used to mechanically terminate cover crops

Pesticide Best Management Practices

Follow the Label

When pesticides must be used, application must be in strict conformance with the label (including any Special Local Needs labels) and other requirements such as Endangered Species protections. Mandatory measures are usually preceded with phrases such as *"must," "do,"* or *"do not."* Mandatory measures may be located in the Environmental Hazards section or in the Directions for Use section (sometimes titled Application Directions).

For example, atrazine labels state: *"This product may not be applied aerially or by ground within 66 feet of the points where field surface water runoff enters perennial or intermittent streams."*

A Lorsban Oregon Special Local Needs (SLN) label states: *"Under this SLN label, the buffer zone that must be followed when making aerial applications to Christmas trees in Oregon is 300 feet."* The SLN label is more restrictive than the federal label found on the container and must be followed.

Endangered species protections may be limited to certain geographic areas and may not be explicitly described on the label. To find out if the pesticide you're using is subject to endangered species protections, visit Bulletins Live! Two (www.epa.gov/endangered-species/endangered-species-protection-bulletins).

For example, interim, no-spray buffers along waterways home to threatened salmon and steelhead in Washington, Oregon and California are currently **required** for nine pesticides (60 feet for ground and 300 feet for aerial applications), though this restriction is not on the label. See Table 4. Consult the EPA Salmon Mapper site (www.epa.gov/endangered-species/salmon-mapper) to identify exactly where the buffers apply.

Use Best Management Practices (BMPs) when the label contains a precautionary statement about toxicity, drift or contamination of water. Using BMPs protects water and people.

Interpret Label to Understand Risks

In addition, pesticide labels and their accompanying Safety Data Sheets (SDS) provide information that alerts users to risks, even when there are no mandatory measures.[32] For example, the label may state:

- *This pesticide is highly toxic to aquatic invertebrates.*

Such precautionary or advisory language is a clue that the user may want to use one or more voluntary Best Management Practices (BMPs), to reduce the risk of harm. Risk mitigation strategies summarized below are drawn from a variety of sources.[33]

Does the Label Warn of Elevated Toxicity?

If any of these phrases warning of high toxicity are present on the label, follow the BMPs to reduce toxic impact:

- *This pesticide is [highly] [extremely] toxic to aquatic invertebrates.*
- *This pesticide is [highly] [extremely] toxic to fish.*
- *Irrigation water treated with this product may be hazardous to aquatic organisms.*
- *Treated [seed] exposed on soil surface may be hazardous.*

Broad-spectrum pesticides (evident when the list of target pests is long) are also risky to many non-targets and should be used with BMPs.

Does the Label Warn of Elevated Potential for Drift?

Labels sometimes mandate or advise drift management. If this phrase is present but mandatory drift reduction measures are not stated on the label, follow the BMPs to reduce drift:

- *Drift from treated areas may be hazardous to aquatic organisms.*

Does The Selected Pesticide Favor "Vapor Drift?"

Section 9 of pesticide SDS sheets includes vapor pressure. Highly volatile pesticides include fumigants and 2,4-D esters. If using a known volatile pesticide or if vapor pressure is larger than 0.01 mm Hg, follow the BMPs to reduce vapor drift.

Does the Label Warn of Aquatic Contamination?

If any of these phrases are present on the label, follow the BMPs to reduce runoff and leaching:

- *Surface Water Advisory (or Surface Water Concern)*
- *Ground Water Advisory (or Ground Water Concern)*
- *potential to run off*
- *may leach*
- *potential for reaching aquatic sediment via runoff*
- *A level, well-maintained vegetative buffer strip…will reduce the potential loading of [chemical] from runoff water and sediment.*
- *Runoff from treated areas may be hazardous to aquatic organisms.*

BMPs to Reduce Toxic Impacts

- Use an alternative practice.
- Use a pesticide that is less persistent and/or less toxic to aquatic invertebrates and fish. Consider a botanical extract or microbial. Both are effective against many pests and widely available.
- Avoid pesticides that have a determination of "Jeopardy" or "Adverse Modification to Critical Habitat" for salmon or steelhead (Table 3) or a history of exceeding Aquatic Life Benchmarks in local streams (Figures 9, 10 and 11).
- Apply the pesticide in a selective manner (such as a bait station, spot treatment, banded row, or alternate row application).
- Choose a selective, rather than broad-spectrum, pesticide.
- Observe setbacks from sensitive habitats.
- Avoid tank mixes or formulated mixes containing multiple active ingredients. Additive effects to aquatic species can result. Synergistic effects are more likely with organophosphates.

BMPs to Reduce Drift

- Apply by ground rather than air when possible. If applying by air, adjust for cross-winds swath displacement and observe adequate setbacks from streams.
- Some ground methods such as airblast sprayers, cannon sprayers and mistigation commonly result in drift. For airblast sprayers, airflow adjustment is an important mechanism to reduce drift.
- Apply only when wind speeds are between 2-8 mph, blowing away from sensitive sites. Wind speeds below 2 mph may indicate inversion conditions which are highly susceptible to drift. Low-tech wind socks are useful for gauging wind direction.
- Spray at the lowest feasible height.
- Select nozzles that produce the largest droplets, using the lowest pressure that will give acceptable coverage. Calibrate equipment.
- Use drift shields or consider adding drift retardants.
- Use precision sprayers (also called intelligent or electrostatic sprayers) or tunnel sprayers to reduce overall pesticide and water use, increase coverage and reduce off-site losses.
- Plant hedges around fields to intercept drift. Relatively narrow hedgerows were found to decrease pesticide deposition in creeks, even with pesticides applied by helicopter.[35]
- Use untreated setbacks next to streams, especially for aerial applications or if no windbreak or drift barrier is present.
- Mitigate dust-off when planting treated seed. Options include applying treatment immediately prior to planting as a liquid or slurry treatment, avoiding dust formulations, or using seed flow lubricants.

BMPs to Reduce "Vapor Drift"

- Select a pesticide with vapor pressures less than 0.01 mm Hg or labeled as "low volatile."
- Avoid application when temperatures during or after application will exceed 70°F and relative humidity is below 40%.

BMPs to Reduce Runoff, Leaching and Erosion

- Avoid applications on impervious surfaces.
- Don't apply pesticides when significant rains or runoff-generating rainfall is expected. Precipitation will drive pesticides toward streams, especially if soils are saturated, bare or bone-dry. Avoid applying pesticides if more than a half-inch of rain is expected in the following 48 hours.
- Avoid highly soluble chemicals and those that are more mobile and more persistent (Table 6), especially prior to or during the rainy season. Find properties at OSU Pesticide Properties Database (npic.orst.edu) or use the University of California IPM WaterTox site (http://ipm.ucanr.edu/TOX/watertox1.php). If their use cannot be avoided, implement other measures to prevent runoff and erosion.
- Less soluble pesticides may still enter streams bound to soil particles. Prevent erosion. Strive to keep the soil surface covered with vegetation and avoid compaction. Drip irrigation and mulching furrows can also reduce erosion.
- For containerized crops, take care to ensure pesticide is applied only to pots.
- If possible, avoid use of pesticides frequently detected in aquatic habitats (Table 8). Frequent detections are an indicator that a pesticide is in widespread use, which promotes pest resistance and creates prolonged exposure for aquatic life.
- Install vegetative filter strips or edge-of-field buffers to intercept erosion and promote infiltration of sheet runoff. While large variability exists, a review found that on average,[36] a 17-foot buffer reduces pesticide loading by 50%; a 33-foot buffer reduces pesticide loading by 90%; and a 67-foot buffer reduces pesticide loading by 97%. Use wider buffers for steeper slopes, heavy runoff, more soluble pesticides, finer textured soils, and higher water tables.
- Wettable powders and microgranular formulations are considered more likely to run off.
- Improve water retention and infiltration in-field. Organic material enhances infiltration and is improved by using cover crops and reducing tillage where appropriate.
- Use strip cropping (perennial vegetation alternated with wider cultivated strips) on contour or straw ropes to slow runoff.
- Channeled runoff leaving a field indicates a need to promote infiltration (such as strip cropping or conservation tillage). Spreaders and berms can distribute runoff over a wider area. Wide, flat, grassy channels ("grassed waterways") promote infiltration of pesticides before the channel meets the stream.
- Treated seeds should be incorporated to a depth of at least 0.75 inch. Clean up any spilled seed.

Examples of conservation practices to reduce drift, runoff and erosion

Sources

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6. Hazelnuts may be underrepresented in Figure 3; hazelnut acreage has grown by an estimated 10,000 acres between 2014-2016. See Sargent, J. (2016, July 22). The Boom in Hazelnuts. Capital Press, p. 1.
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9. Diet preferences summarized in National Marine Fisheries Service, 2015. Endangered Species Act Section 7 Consultation Conference and Biological Opinion: Environmental Protection Agency's Registration Of Pesticides Containing Diflubenzuron, Fenbutatin Oxide, and Propargite, p. 64, p. 160, and p. 454.
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11. Bio-Surveys, LLC. 2014 Rapid Bio-Assessment in the Pudding River Basin. http://puddingriverwatershed.org/sites/default/files/pdfs/2014 Pudding Presentation.pdf.
12. Data sources include ODFW and NMFS, Upper Willamette Recovery Plan (endnote 7); NMFS, 5-Year Review (endnote 10); Keefer M. and Caudill, C. 2010. A review of adult salmon and steelhead life history and behavior in the Willamette River Basin. Technical Report 2010-8, Prepared for the U.S. Army Corps of Engineers; and Mobrand Biometrics, 2004. Appendix P EDT Assessment of Aquatic Habitat in the Clackamas Subbasin, Draft prepared May 14, 2004. https://www.nwcouncil.org/media/23073/App_P_EDT_Assessment_Clack.pdf.
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14. Ibid, Tables 5-7, 5-8.
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16. See for example: Baldwin , D., Spromberg, J. Collier, T., and Scholz, N. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations Ecological Applications 19: 2004–2015. doi:10.1890/08-1891; Laetz C., Baldwin D., Hebert V., [and others]. 2013. Interactive neurobehavioral toxicity of diazinon, malathion, and ethoprop to juvenile coho salmon. Environmental Science and Technology 47: 2925–2931; and Tierney K., Baldwin D., Hara T. [and others]. 2010. Olfactory toxicity in fishes. Aquatic Toxicology 96:2-26.
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19. Inferences must be drawn from monitoring programs because a) sample locations may not be representative of habitats and locations used heavily by salmonids; b) sample timing may not reflect peak concentrations; c) the durations of exposure remain unknown. Therefore, monitoring data alone may underrepresent or overstate the risk.
20. Within the Clackamas subbasin, sediment samples were collected in 2014. Some pesticide residues were detected, mainly bifenthrin.
21. Based on aggregated data across the Clackamas, Molalla-Pudding and Yamhill PSPs. Atrazine and simazine have been grouped together in this analysis since they are molecularly very similar and create the same degradate products.
22. A non-detect only indicates that the pesticide is not present in the sample at laboratory-capable detectable levels. In this analysis, mean concentrations have been calculated by assigning non-detections a value of zero. An alternative technique is to assign a non-detect the lowest value that can be detected in the lab, rather than zero, since there is no way to know if the pesticide is actually absent or is only present at levels below detection capability. Therefore, mean concentrations discussed in this report may underrepresent actual average aquatic concentrations.
23. In this report, the most recently revised EPA ALB for atrazine is used. The new benchmark level is now at 0.001 ug/l.
24. Hope, B. 2012. Cited in National Research Council, 2013. Assessing risks to endangered and threatened species from pesticides.
25. Nowell, L., Norman, J., Moran, P. [and others]. 2014. Pesticide toxicity index—a tool for assessing potential toxicity of pesticide mixtures to freshwater aquatic organisms. Science of the total environment, 476, pp.144-157. See also Cedergreen, N., 2014. Quantifying synergy: a systematic review of mixture toxicity studies within environmental toxicology. PloS one, 9(5), p.e96580. doi:10.1371/journal.pone.0096580. Cedergreen defined synergy and antagonism as a greater than 2-fold difference from expected effects using concentration addition.
26. Half-lives are specific to the conditions under which breakdown occurs – for instance, in soil or water and under aerobic or anaerobic conditions. Different conditions and breakdown mechanisms (e.g. photolysis, hydrolysis, or metabolism) can result in different half-lives for the same pesticide.
27. Environmental fate properties are part of testing for pesticide registration. Actual values can vary in the field based on temperature, pH, soil type, soil organic matter, and other conditions. Other sources for environmental fate information include the USDA ARS Pesticide Properties Database, at https://www.ars.usda.gov/northeast-area/beltsville-md/beltsville-agricultural-research-center/crop-systems-and-global-change-laboratory/docs/ppd/pesticide-list/ and Mackay, D., Shiu, W. Y., Ma, K. C., & Lee, S. C. (2006). Handbook of physical-chemical properties and environmental fate for organic chemicals. CRC press.
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29. Parke, J. 2016. Soil solarization in container nurseries and field production. Digger Magazine, February 1, 2016. http://www.diggermagazine.com/soil-solarization-in-container-nurseries-and-field-production/. Also see Funahashi, F. and J. Parke. 2016. Effects of soil solarization and Trichoderma asperellum on soilborn inoculation of Phytophthora ramorum and Phytophthora pini in container nurseries. Plant. Dis. 100:438-443.
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The Northwest Center for Alternatives to Pesticides works to protect community and environmental health and inspire the use of ecologically sound solutions to reduce the use of pesticides.